FOREST PEST MANAGEMENT
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A BIOLOGICAL EVALUATION OF PEST CONDITIONS AT FIVE SOUTHERN CALIFORNIA SKI AREAS, SAN BERNARDINO NATIONAL FOREST

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ABSTRACT

Five ski areas on the Arrowhead and Big Bear Ranger Districts, San Bernardino National Forest, were evaluated for the presence of insects and diseases and overall stand health and vigor. White fir true mistletoe and annosus root disease were causing the most damage. Alternatives including no action, regeneration, thinning, and sanitation are presented for use by the Forest in the development of vegetative management plans for the areas.

INTRODUCTION

Five developed winter resorts are found on the Big Bear and Arrowhead Ranger Districts. These resorts are operated in partnership between the Forest Service and ski area operators. To ensure that forest visitors receive quality outdoor recreation within environmentally sound ski area developments, vegetative management plans are being developed by the San Bernardino Forest for each ski area.

The objectives of these plans are: to maintain the existing forested landscape; to improve the health and vigor of existing vegetation; and to provide for a continuous succession of vegetation. The Forest is concerned that insect and disease pests may adversely affect these goals, and requested a biological evaluation to determine how pests may affect their management objectives.

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OBSERVATIONS

Snow Valley

Snow Valley, located 5 miles east of Running Springs on Highway 18, has 13 chairlifts on 230 acres (see maps in Appendix). It is on a north-facing slope and benefits from the increased available moisture.

Vegetation is dominated by white fir, especially in the understory, and stocking levels are generally high. The stands are 2 or 3 storied. The overstory is Jeffrey pine and white fir, with scattered sugar pine. Cover ranges from 10% to 40%. Intermediates, when present, consist of white fir, black oak and incense-cedar, and cover is 0 to 30%. Smaller trees are white fir, incense-cedar and black oak, with a few planted giant sequoia. Cover is 30 to 60%. Brush species present include whitethorn, greenleaf manzanita and chinquapin.

The pests found at Snow Valley are listed in the table below.

PEST	COMMON NAME	HOST	IMPACT	DISTRIBUTION
Phoradendron bolleanum	True mistletoe	WF[1]	severe	widespread
Heterobasdion annosum	Annosus root disease	WF	moderate	1 center
Arceuthobium campylopodum	dwarf mistletoe	JP	moderate	heavy in spots
Scolytus ventralis	Fir engraver	WF	moderate	scattered pockets
Ips spp.	Pine engraver	JP	low	few trees
Thomomys bottae	Gophers	all	low	widespread
Man	Construction	all	moderate	scattered

1. WF, white fir; JP, Jeffrey pine.

Heterobasidion annosum (Fomes annosus) was found in only one area. Conks were present in a white fir stump northeast of "Stemtation" run, in a rocky, brushy area composed of chinquapin, and other brush species, and a few scattered white fir, sugar pine and black oak. The root disease is active and partially responsible for lack of trees in this portion of the ski area.

White fir true mistletoe is present throughout the ski area wherever true fir is present. Infection levels vary from light to severe. Where it is severe, the mistletoe is preventing understory and intermediate trees from reaching overstory height by killing tops and predisposing them to premature insect attack.

Levels of western dwarf mistletoe in Jeffrey pine ranged from light to moderate. Western dwarf mistletoe will spread slowly in the Jeffrey pine on the lower slopes because of the mixed species stands. Lateral spread will be interrupted in some directions and the rate of spread will be slower than average (1 to 2 feet per year). The disease will intensify in individual trees and these trees will become increasingly susceptible to bark beetle attacks.

Green Valley

Green Valley is a 40 acre ski area with 1 chairlift and 2 poma lifts located south of Green Valley Lake, approximately 6 miles east of Lake Arrowhead.

The overstory is Jeffrey pine, white fir, and black oak, with some sugar pine and incense-cedar. Understory species include white fir, oak, Jeffrey pine, and a few incense-cedar. The area is very open. There are few to no trees on slopes, and mats of whitethorn occur on some runs. The east side of the ski area is predominantly oak.

In general, the overall appearance of the vegetation is lackluster. Trees at the top of the area are stunted and windswept. This ridge is a harsh site for tree growth. Many of the slopes are bare, wind erosion occurs on areas of exposed earth, and side gullys have formed due to water run off. Islands of vegetation between open areas are quite small and exposed to winds.

The pests found at Green Valley are listed in the table below.

PEST	COMMON NAME	HOST	IMPACT	DISTRIBUTION
Phoradendron bolleanum	True mistletoe	WF	severe	widespread
Scolytis ventralis	Fir engraver	WF	moderate	scattered
Phaeolus schweinitzii	Red-brown butt rot	JP	none	1 stump

White fir true mistletoe is the most damaging pest in the area. This parasitic plant is causing tree deformity, reduced vigor and dead tops. The fir engraver, Scolytus ventralis, is also present. Attacks in lower crowns have been pitched out, but attacks in upper crowns have resulted in dead tops. Phaeolus schweinitzii, a decay fungus that causes a brown cubical rot, was found near a Jeffrey pine stump on the eastern boundary of the ski area. This decay fungus can be a hazard in standing trees.

Bear Valley (Goldmine)

Bear Valley ski area, formerly called Goldmine, offers 1800 vertical feet of skiing over 250 acres. Base area elevation is 7100 feet. Elevation at the top of the highest chair is 8900 feet. The resort has snow making capability on all its runs. There are 5 double chairlifts, and 3 triple chairlifts with a total carrying capacity of 10,000 skiers. The resort is located near the eastern end of Big Bear Lake.

The overstory is primarily white fir and Jeffrey pine, with some incense-cedar and sugar pine. Black oaks are scattered throughout the lower elevations. Basal area varies from 140 to 300 sq. ft. per acre in forested areas. Diameter at breast height is as large as 45 inches. Above 8000 feet the vegetation shifts, with juniper, limber pine and shrub species such as manzanita dominating.

The following pests were detected at Bear Valley Ski Area:

PEST	COMMON NAME	HOST	IMPACT	DISTRIBUTION
Heterobasdion annosum	Annosus root disease	WF,JP	major	17 centers in WF, 2 in JP
Phoradendron bolleanum	True mistletoe	WF	severe	widespread
Arceuthobium campylopodum	Western dwarf mistletoe	JP	moderate	scattered
Elytroderma deformans	Elytroderma disease	JP	moderate	scattered
Cytospora abietis	Cytopspora canker	WF	low	scattered
Scolytis ventralis	Fir engraver	WF	moderate	scattered
Phoradendron juniperinum	Juniper mistletoe	JU[1]	none	scattered
Dendroctonus jeffreyi	Jeffrey pine beetle	JP	low	scattered
Armillaria mellea	Armillaria root disease	WF	none	scattered
Echinodontium tinctorium	Indian paint fungus	WF	none	few trees
Peridermium harknessii	Western gall rust	JP	none	few trees
Ips spp.	Pine engraver	JP	low	scattered
Phaeolus schweinitzii	Red-brown butt rot	JP	none	few trees
Tetropium abietis	Roundheaded fir borer	WF	none	few trees
Melanophila drummondi	Flatheaded fir borer	WF	none	scattered
Fomitopsis pinicola	Brown crumbly rot	WF	none	few trees
Arceuthobium cyanocarpum	Dwarf mistletoe	LP	none	scattered
Man	Mechanical damage	all	moderate	scattered

1. JU, juniper; LP, limber pine

Annosus root disease and white fir true mistletoe are severe. Annosus root disease is causing scattered pockets of mortality throughout. The true mistletoe on white fir is causing severe deformity, spike tops, and mortality is widespread on overstory trees. There are large areas where it is difficult to find trees not infected with true mistletoe.

Western dwarf mistletoe, Elytroderma needle disease, fir engraver, and mechanical damage are causing a significant amount of mortality and/or deformity throughout the ski area. The remainder of the pests listed are not presently impacting the vegetation significantly.

Snow Summit

Established in 1952, Snow Summit operates 10 chairlifts on 620 acres. The vertical drop is over 1150 feet. It is located near the eastern end of Big Bear Lake adjacent to Highway 18. Most runs can open and every chair can operate with man-made snow alone.

The lower slopes of Snow Summit (elevation 7000') consist of open grassy areas. Forested stands do not begin for a few 100 feet from the base area. These stands are comprised of an overstory of white fir and Jeffrey pine with occasional sugar pine and incense-cedar. Pockets of black oak are present. Some white firs are 50" dbh, and basal area varies from 120 to over 200 sq. ft. per acre. The understory is predominantly white fir with Jeffrey pine, sugar pine and incense-cedar.

Pests observed include:

PEST	COMMON NAME	HOST	IMPACT	DISTRIBUTION
Phoradendron bolleanum	True mistletoe	WF	severe	widespread
Heterobasidion annosum	Annosus root disease	WF,JP	major	16 centers in WF, 2 in JP
Arceuthobium campylopodum	Western dwarf mistletoe	JP	moderate	scattered
Scolytus ventralis	Fir engraver	WF	moderate	scattered
Elytroderma deformans	Elytroderma disease	JP	low	scattered
Cytospora abietis	Cytospora canker	WF	low	scattered
Dendroctonus jeffreyi	Jeffrey pine beetle	JP	low	scattered
Armillaria mellea	Armillaria root disease	WF	none	scattered
Peridermium harknessii	Western gall rust	JP	none	scattered
Ips spp.	Pine engraver	JP	low	scattered
Melanophila drummondi	Flatheaded fir borer	WF	none	scattered

Man	Construction damage	all	moderate	scattered
Weather	Lightening, wind	all	low	scattered

Annosus root disease is causing mortality throughout the site, primarily in white fir. Under present conditions small groups of trees will continue to die. When these disease centers are located along ski runs, chairlifts, roads or buildings they will pose a hazard and create unsightly vegetation.

Also present throughout are dead and dying trees caused by construction injury. The majority of the damage is due to soil movement and subsequent burial of tree roots. White fir are also suffering from scars caused by machinery rubbing up against trees. These scars provide infection courts for decay fungi which cause further deterioration. When these are located in high use portions of ski areas they could eventually become hazardous.

Most pests rated moderate or above (true fir true mistletoe, annosus root disease, western dwarf mistletoe and mechanical injury) are sufficiently damaging to warrant consideration when developing stand management alternatives for this area.

Snow Forest

Overlooking Big Bear Lake and Bear Valley from above Big Bear Village, Snow Forest covers 160 acres with 3 surface lifts, one poma lift and one 3,000 foot triple chair lift with a capacity of over 1,500 skiers per hour. The ski area is divided into 2 sections, Siberia Mountain, a relatively flat area offering beginning and low intermediate skiing, and Lynn Mountain with steep and moderate terrain.

The overstory is comprised of white fir, Jeffrey pine, black oak and scattered sugar pine. The understory is predominately white fir with Jeffrey pine and some oak. Brush species include manzanita, whitethorn, and chinquapin.

The following pests were found at Snow Forest:

PEST	COMMON NAME	HOST	IMPACT	DISTRIBUTION
Phoradendron bolleanum	True mistletoe	WF	severe	widespread
Arceuthobium campylopodum	Western dwarf mistletoe	JP	low	scattered
Scolytus ventralis	Fir engraver	WF	moderate	scattered
Dendroctonus jeffreyi	Jeffrey pine beetle	JP	low	scattered
Peridermium harknessii	Western gall rust	JP	none	few trees
Man	Construction damage	all	moderate	scattered

True mistletoe on white fir is causing considerable damage. There are numerous deformed trees and spike tops due to infection by this parasite. Infection levels vary from light to severe, with scattered mortality present in the most heavily infested areas. The understory is also infested.

MANAGEMENT ALTERNATIVES

The health and vigor of the trees in the ski areas examined is a product of both stand conditions and the pests that are present. Silvicultural treatments that favor good growing conditions will significantly decrease pest activity. One or more of five alternatives could be used in these areas: Do Nothing, Thin, Sanitize, Regenerate and Hazard Tree Management.

1. Do Nothing. Stands with few pest problems, appropriate stocking levels and regeneration can be expected to maintain themselves for several decades with little or no manipulation. Because basal area will gradually increase over time, thinning may eventually be necessary.

In overstocked stands with true mistletoe and/or annosus root disease, tree mortality will continue to fluctuate with yearly precipitation levels. Top-killing of white fir will occur as a result of mistletoe infection, fir engraver attack and high stocking levels. Top-killing frequently develops into whole tree mortality on sites where stress is recurrent.

Even though mortality will continue, the general stand appearance will remain similar to its current condition. Specific areas may change as small openings are created and regenerate. As the Jeffrey pine in the overstory ages and dies, the shade-tolerant white fir will replace it.

2. Thin. Various thinning regimes could be used to increase vigor, prolong the life of the stand, and prevent or reduce pest build-up. In even-aged stands with no reproduction and few pests, removing suppressed and intermediate trees would accomplish these goals, particularly when drought conditions occur. Thinning dense aggregations of young trees will prevent stagnation and reduce the risk of future insect attacks.

In areas dominated by white fir infested with true mistletoe, thinning could be used to change the understory composition so that future stands have more pine and less fir, thereby reducing the number of trees susceptible to this host specific parasite. Since white fir is the predominant species in most areas, this action will also increase overall diversity.

3. Sanitation. Sanitation will lower basal area and produce some of the same benefits as thinning, but its primary value is to remove sources of inoculum (for example fertile true fir mistletoe berries) that could be spread to adjacent trees. Hazardous trees can also be evaluated and removed in the process of sanitation, making the area safer for human use.

4. Regenerate. Several stands have an overstory that is relatively unaffected by pests but have little or no regeneration beneath. These stands could be perpetuated if regeneration was established.

Other stands have overstory trees that are heavily impacted by pests and regeneration with a nonsusceptible species would be highly beneficial.

5. Hazard Tree Management. The periodic inspection and treatment of trees that pose a threat to human safety or investments is already occuring in all ski areas visited. Trees injuried by construction or fire, particularly true fir, are likely to become infected with root and butt rot, and are more susceptible to insect attack. Trees with dead tops are prone to infection by decay fungi and may become hazardous to skiers. Hazard tree maintenance should be an integral part of any ski area vegetation management plan. The completion of these activities in a thorough and timely manner is advised.

Pest-specific Alternatives

Pest-specific alternatives for H. annosum, true fir true mistletoe, dwarf mistletoe, pine engravers and gophers are presented below.

Annosus Root Disease. No direct methods are currently available for controlling or eliminating annosus root disease once it is established in a stand. Strategies available to reduce the impacts of Heterobasdion annosum include taking action to: a) prevent the initiation of new centers by reducing the probability of stump infection and b) implement silvicultural treatments in infested stands to minimize disease effects. Alternatives include the following:

a. Prevent stump infection. Application of granular borax to freshly cut conifer stumps is effective in preventing most (90%) new infections. The chemical is toxic to the spores of H. annosum, but has no effect on existing infections. Borax application within a few hours of tree felling is required on all conifer stumps cut in and near developed recreation sites (FSM R-5 Supp. 164, FSM 2303.14, 9/86).

b. Regulate species composition. This alternative involves revegetating the openings created by the root disease-related mortality with species not susceptible to H. annosum. Since H. annosum spreads readily from pines to other conifers and can infect all conifers in California, the best option for regenerating active annosus centers is with nonsusceptible hardwoods or shrubs. Observations indicate that H. annosum centers in true fir can be successfully revegetated with pines.

c. Utilization of openings. It is possible to use openings created by root disease for parking lots, ski runs, picnic areas, administrative sites, etc. Some mortality, creating potentially hazardous tree conditions, may occur around the edges of these areas.

True Mistletoe on White Fir. Control of true mistletoe is difficult in forest stands. To eliminate the parasite, the infected limbs must be pruned off, or if infection is severe, the entire tree removed. Both of these alternatives are costly and are seldom economically feasible. Eradication of the pest from an area does not insure protection from further infecton. Birds are likely to reintroduce the parasite from nearby infected areas. About 5 to 10 years are required however, for the parasite to build up to damaging

proportions before control is again necessary. Planting tree species that are not susceptible to local mistletoe is a sound approach to control.

Dwarf Mistletoe. The long-term effect of dwarf mistletoe is decadence and possible loss of the host species as a stand component. A series of actions are possible in high value areas to reduce the impact and intensity of the mistletoe and retain the natural appearance of the stand.

Control alternatives --

Dwarf mistletoe treatments may include one or any combination of the following:

1. Removing infected overstory trees to protect regeneration.
2. Removing witches' brooms to prolong tree life.
3. Removing all infections by pruning to eliminate the parasite.
4. Removing heavily infected trees that cannot be successfully pruned.
5. Thinning to remove infected trees and release residual trees.
6. Destroying heavily infected stands or aggregations and then regenerating.
7. Creating buffer strips to prevent reentry of dwarf mistletoe.
8. Favoring resistant species (includes planting).

Forest Pest Management may be able to financially assist presuppression surveys designed to gather mistletoe information and for subsequent suppression projects. When funding presuppression surveys, we assume the Forest and District are committed to using the information to develop stategies for reducing pest impact. Forest Pest Management is available to provide whatever assistance or additional information is requested by the District or Forest.

Retaining old-growth trees, particularly pines, is desirable in the ski areas. Diminishing vigor is characteristic of these trees and dwarf mistletoe infection adds additional stress. It may be possible to prolong individual tree life by removing large mistletoe-induced witches' brooms, as long as one third of the crown still remains after pruning. These witches' brooms act as sinks, robbing the host tree of nutrients. This procedure does not completely eradicate the mistletoe from the area and understory trees may become infected.

Pine Engravers. Fresh pine slash caused by thinning, dwarf mistletoe control work, construction or winter storm breakage can be modified in a number of ways to make it unsuitable for pine engraver breeding. One approach to minimizing damage is to schedule slash-generating activities mostly between mid-July and late-December. Populations will not have a chance to build to high levels in the first half of this period and overwintering mortality will reduce the number of ips present. Slash created during the last half of this period will be unsuitable as host material at the time of beetle flight the

following spring. Utilization of the cut material to the smallest possible diameter will minimize the amount of breeding material available to engraver beetles. If green pine slash must be created during the spring and early summer, slash treatments are available to prevent the buildup of pine engraver populations. Because pine engravers can complete their development in about a month under ideal conditions in Southern California, treatment should be carried out soon after cutting to be effective.

Slash treatment methods which generally work well include chipping, lopping and scattering slash in sunny areas, crushing or mashing slash with logging equipment to make it unsuitable for pine engraver breeding, or piling and burning the slash within a month of cutting. Broadcast burning the slash might work if it could be done without damaging the residual stand. A method which has worked during the summer in hot climates is to pile slash in a sunny area and tightly cover the pile with clear plastic. If the temperature under the bark in all parts of the pile reaches more than 120°F, all brood currently in the pile will be killed. Lower temperatures will not be effective and, where successful, this method will not prevent reinfestation of slash piles. Because most pine engraver attacks occur within a quarter-mile from the location where the beetles emerged, high value pines can be given some protection by removing fresh pine slash to areas which do not have pines.

Two practices which should generally be avoided are piling fresh pine slash without further treatment, and allowing slash to touch or remain near valuable leave trees.

Pocket Gophers. Gophers are not currently a problem in the areas evaluated, but should be considered as a potential problem if alternatives involving regeneration are implemented. If no control action is taken, pocket gophers may seriously hinder or prevent the establishment of vegetation in open areas. The most appropriate time to initiate control of pocket gophers is prior to planting/transplanting when populations are naturally low and chances of maintaining them at non-damaging levels are increased. Maintenance treatments should be conducted during the establishment period. Pocket gopher management alternatives include trapping, fumigation, and baiting. The most practical method of controlling large numbers of gophers is to place toxic baits underground by hand probing or by use of a mechanical burrow builder. Of the rodenticides that are readily available, strychnine alkaloid is the most effective toxicant. For cleanup work or for small areas where only a few animals are involved, trapping is an effective means of control. Fumigation is generally unsatisfactory because of the extent of the burrow system and the fact that gophers may plug off their burrows when the fumigant is detected.

SUMMARY

The majority of pests found at each area are rated as having low or no impact on stands and should not affect vegetation management options. Those rated moderate or severe, particularly annosus root disease and true fir true mistletoe, do need to be considered when stand management plans are written. The pest specific alternatives discussed could become an integral part of the vegetation management plans for the areas.

PEST BIOLOGIES

ANNOSUS ROOT DISEASE

Heterobasidion annosum is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (Artemisia menziesii), and a few brush species (Arctostaphylos spp. and Artemisia tridenta) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is also very high in Southern California recreation areas on the San Bernardino and Cleveland National Forests.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, H. annosum grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness. Losses in true fir from H. annosum are mainly the result of windthrow resulting from root decay, and reduced root systems which predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

In general, infections will cross from roots of pine to roots of true fir; however, rarely is the fungus observed to cross from true fir to pine. At higher elevations where pine and true fir are intermixed, H. annosum is commonly found only on true fir and mortality rarely includes both species within an infection center.

WHITE FIR TRUE MISTLETOE

White fir mistletoe, Phoradendron bolleanum ssp. pauciflorum, is a true mistletoe having small, green leaves and round, white berries. It can only survive in living white fir tissues, principally as a water parasite utilizing water and minerals from the host. In California, it is limited geographically to the Sierra Nevada south of Interstate 80, and to the mountains of southern California.

This pest is spread mainly by birds, including robins, bluebirds, thrushes, phainopeplas, and cedar waxwings. Birds feed on the berries, digest their pulp, and excrete the living seed, often depositing them onto susceptible trees. A viscous coating and hair-like threads on the outer surface of the seeds attach them firmly to twigs and branches, where they germinate and infect host tissues.

In nearly all cases, initial infection occurs on the branches of larger or older trees because birds prefer to perch in their tops. Severe buildup of mistletoe often occurs in an already-infected tree because birds are attracted to and may spend prolonged periods feeding on the mistletoe berries.

Heavily infected trees are weakened, reduced in growth rate, and sometimes killed. Weakened trees are predisposed to attacks by insects and often die during drought or other periods of stress. Severe infection of white fir can result in top-kill in combination with the fir engraver (Scolytus ventralis). Branches and tree tops heavily-laden with true mistletoe often break during wind storms, increasing the hazard to people and property in campgrounds and other developed sites.

White fir mistletoe is recognized by the clumps of mistletoe foliage in the tree. These mistletoe plants are usually in the tops of larger, older trees. With severe infections, virtually all of the tree's foliage may be replaced by mistletoe plants. Dead spike tops are common in white fir stands heavily infected by this parasite.

POCKET GOPHER

The pocket gopher, Thomomys bottae, is a rodent in the family Geomyidae. They spend most of their life in an extensive tunnel system. The surface openings to their tunnel system are kept well plugged except while burrowing, gathering food a few inches around feed holes, or sometimes following rains. They are highly solitary individuals except when mating or when a mother has young, usually fighting to the death if two are put together.

Pocket gophers do not hibernate and, when burrowing under snow, they deposit the excavated earth in abandoned snow tunnels. The earth cores become visible when the snow thaws.

There is one litter per year born in late spring or early summer. Litter size averages 5 or 6 but may range from one to more than a dozen. Dispersal of the young is often done above ground in late summer or early fall. The population turnover rate is often 70-80% per year due to natural causes.

Pocket gophers feed on a great variety of forbs, grasses, seeds, acorns, tubers, bulbs, roots, bark of trees, and when protected by snow, they gnaw on branches and main stems of conifers several feet above ground.

FIR ENGRAVER

The fir engraver (Scolytus ventralis) attacks both white and red fir in California. Trees ranging in size from large saplings to overmature sawtimber

are susceptible. Attacks can cause patch-killing of cambium along the bole, top-kill, or tree death. Top-kill or death occur most often in firs that have been weakened by root disease, dwarf mistletoe, overstocking, soil compaction, sunscald, logging injury, or drought. The fir engraver also breeds in slash and windthrown trees.

The fir engraver usually completes its life cycle in one year, sometimes two. Adults fly and bore into trees or green fir slash from June to September; larvae, pupae, and adults over-winter under the bark. Pitch tubes are not formed as they are with pine bark beetles; the usual evidence of attack is boring dust in bark crevices along the trunk and pitch streamers on the mid and upper bole. Trees colonized early in the summer may begin to fade by early fall, but those colonized later in the year usually do not fade until the following spring or summer, often after the beetles have emerged.

DWARF MISTLETOE

Dwarf mistletoes (Arceuthobium spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of Digger pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached, and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

ELYTRODERMA NEEDLE DISEASE

The fungus Elytroderma deformans causes the most serious needle disease of ponderosa and Jeffrey pines in California. Occasional hosts include lodgepole, knobcone, Coulter, and pinyon pines. Unlike other needle diseases, Elytroderma infects twigs and branches systemically, allowing continued reinfection of a host's new needles even under adverse environmental conditions. Elytroderma impact is most severe in recreation forests, where the unsightly appearance of infected trees and occasional mortality can degrade the appearance and health of a stand.

Fungal fruiting bodies (hysterothecia) release spores from infected needles in late summer and early fall. Spores are windborne to susceptible hosts and, if environmental conditions are suitable, they germinate and infect the current year's needles. Initially, the fungus grows through the needle and into the twig without killing the needle. The following spring, infected needles die and turn a conspicuous red-brown. Infected branches take on a characteristic appearance, with current year's needles looking green and healthy while the one-year-old, infected needles are bright red-brown. Long, narrow, dull black fruiting bodies form on all surfaces of the dead needles and mature later in the summer, completing the infection cycle.

Fungal mycelium within the twigs spreads into the growing tips and buds, deforming future branch growth. As a result, infected branches have a broomed appearance similar to that caused by dwarf mistletoes. However, Elytroderma brooms are distinguished by several characteristics: the red-brown color of one-year-old needles in spring and early summer; fruiting bodies scattered over the needle surface; resinous, brown necrotic lesions in the inner bark of twigs and branches infected for three years or more; and, a lack of mistletoe shoots or basal cups.

Elytroderma disease kills one-year-old needles prematurely and deforms infected twigs and branches. Generally, pines are little affected if fewer than 40 percent of the twigs are infected. The disease seldom kills mature trees directly, but moderate-to-severe infection can predispose them to bark beetle attack. The disease is most severe on seedlings, saplings, and poles that are suppressed or have thin crowns. Disease outbreaks are uncommon, but once started, the disease can persist for many years, particularly in moist sites.

PINE ENGRAVER BEETLES

Pine engraver, (Ips spp.), attacks have been recorded on most species of pines in California. These beetles kill saplings, poles and sawtimber up to about 26 inches dbh and the tops of even larger trees. Attacks on live trees are usually limited to trees which are suppressed, or stressed by dwarf mistletoe, root disease, drought, fire or the attack of other insects. If fresh slash is available in the spring, pine engravers may build up in an area and cause localized mortality or top killing by mid-summer.

Attacks are made with the coming of warm weather in the spring. Attacking males bore nuptial chambers in the inner bark and release a pheromone which attracts other beetles to the attack site. If many beetles are attracted, they may attack nearby trees and cause a group kill. Within a day or two of the

attack by the male, two to five females enter the nuptial chamber and after mating, each female bores an individual egg gallery which lightly scores the sapwood. The size and pattern of the combined gallery pattern is often diagnostic of the species of Ips involved. The galleries are kept open by beetles pushing boring dust out through the entrance hole. Red boring dust collecting in bark crevices or spider webs is diagnostic of a successful attack. Eggs are laid in niches along the sides of the galleries. Larvae hatch from the eggs and feed in the phloem. They eventually pupate in cells at the end of their larval mines and transform to adults.

A new generation is produced in as little as 6-8 weeks in the spring to 4-6 weeks in mid-summer (August). Thus, several overlapping generations per year may be produced. The winter may be passed in any of the life stages of larvae, pupae, or adults, depending upon which Ips species is involved.

Outbreaks in standing, healthy trees are sporadic and of short duration, and are often associated with some temporary stress or shock afflicting the host species, such as drought or logging disturbance. Tree killing frequently occurs where green pine slash, which serves as breeding habitat is left untreated during spring and summer. To be suitable as pine engraver breeding habitat, pine slash must have bark from 1/8 to 1 inch thick (usually 3 to 26 inches diameter), must have succulent cambium and must remain moderately cool during the development period.

ARMILLARIA ROOT DISEASE

Armillaria sp. is widely distributed in soils and usually lives as a saprophyte on dead wood or other organic matter. This fungus has a wide host range, including virtually all woody plants in California. It is frequently associated with hardwood roots, especially oaks. Healthy oaks are resistant to the fungus. This resistance disappears, however, when trees are weakened, stressed, cut, or killed, and Armillaria sp. may then rapidly colonize and decompose roots and sometimes entire root systems. Stresses that have been linked to increased damage from this root disease include insect defoliation, drought, excessive soil moisture, poor planting techniques, bark beetle attack, air pollution injury, and nutrient deficiencies.

The organic material used as a source of nutrition is called a food base. With a large food base to utilize, the fungus becomes more aggressive and moves to the roots of nearby trees by means of root contacts and rhizomorphs. Rhizomorphs are structures that resemble black shoestrings and grow like roots through upper soil layers. The predominant method of tree to tree spread in California is via root contact; rhizomorphs are more important and prevalent in other areas of the country.

Armillaria sp. is capable of directly penetrating through the intact root bark of living trees and once it reaches the cambium it usually grows rapidly, producing a flat, white, leathery, fan-shaped mycelial mat. Rhizomorphs are often associated with the mat. If the fungus reaches the root collar it girdles the stem and kills the tree. After Armillaria sp. successfully colonizes a root segment or root system, it continues to decay the wood and causes a white to yellowish, wet, stringy rot. This rot does not usually extend more than a few feet above the soil line.

Clusters of mushrooms may be found in the fall at the base of infected dead or dying trees and stumps. These mushrooms may also grow directly out of the soil near the food base. Spores produced by fruiting bodies are not an important source of new infections or long distance spread.

INDIAN PAINT FUNGUS

The primary hosts of the indian paint fungus, Echinodontium tinctorium, in California are the true firs. Infection results in a brown stringy rot of the heartwood that may result in a hollow being formed. Conks of the fungus are very distinctive, being dark and woody with a rust red interior. The lower surface has hard, coarse teeth or spines while the upper surface is black and rough. When a tree bears two or more conks that are separated by more than 10 vertical feet, then extensive decay of the heartwood is present. Individual conks less than 6 inches across usually indicate that the decay has not reached the advanced stringy stage.

Infection occurs when spores germinate on stubs formed from the breaking of shade-killed branchlets less than 1 mm in diameter. These stubs are overgrown by new wood and the fungus remains quiescent for up to 50 years causing no decay. It is postulated that the formation of large branch stubs or wounds may cause reactivation of the fungus, resulting in decay.

CYTOSPORA CANKER

Cytospora abietis is a canker-causing fungus that infects true firs throughout their range in California. It is a weak parasite, and usually attacks trees that have been weakened by disease, drought, fire, insects, or human disturbance. It is most commonly associated with dwarf mistletoe infection, and sometimes attacks as many as a quarter of the mistletoe-bearing branches, killing many each year. The bright red flags of recently-killed branches on dwarf mistletoe-infected red firs are almost always the result of lethal Cytospora infections. C. abietis occasionally reaches especially damaging proportions in certain years, and may attack trees of any age, sometimes killing the tops or all of young trees.

APPENDIX

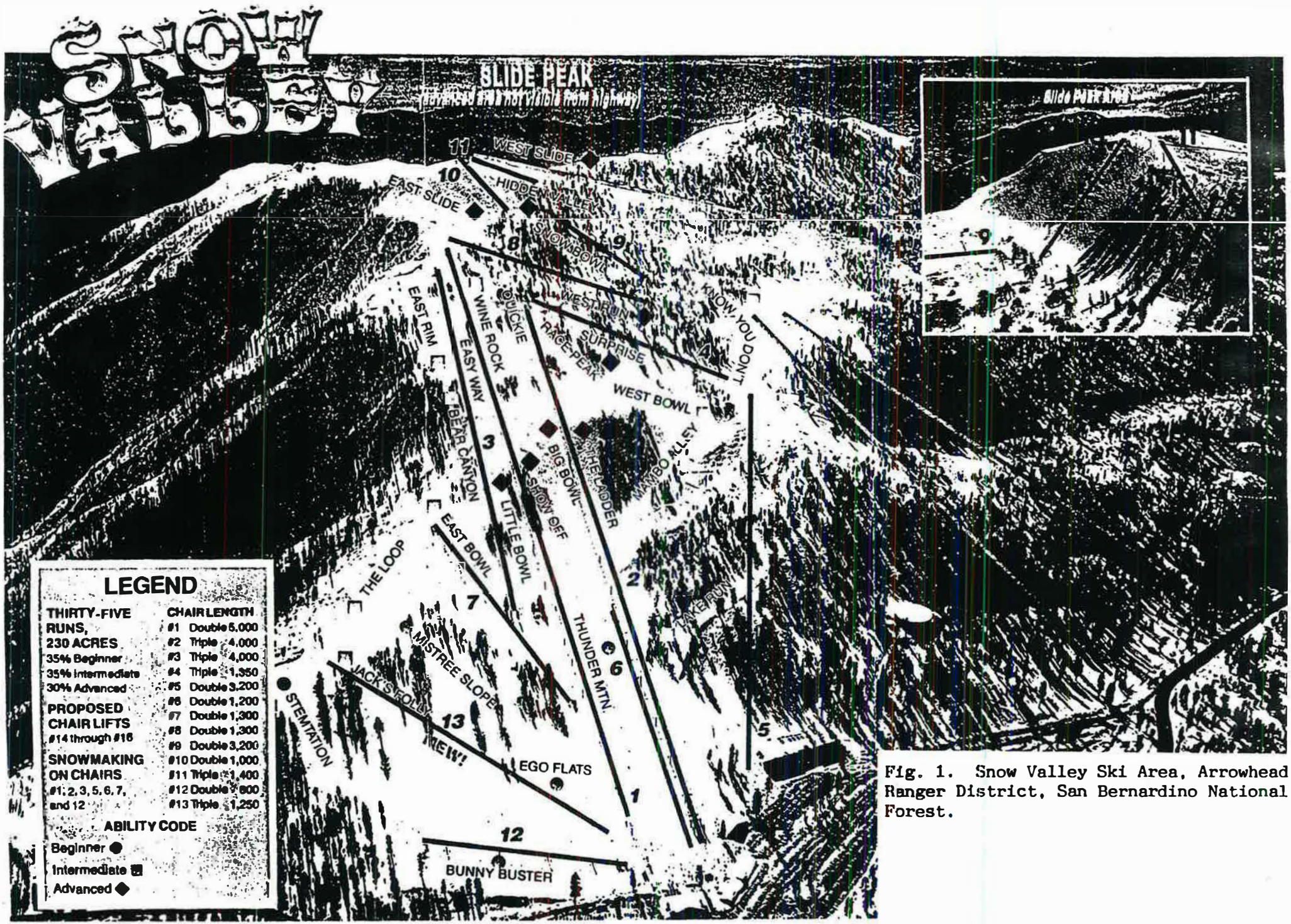

Fig. 1. Snow Valley Ski Area, Arrowhead Ranger District, San Bernardino National Forest.

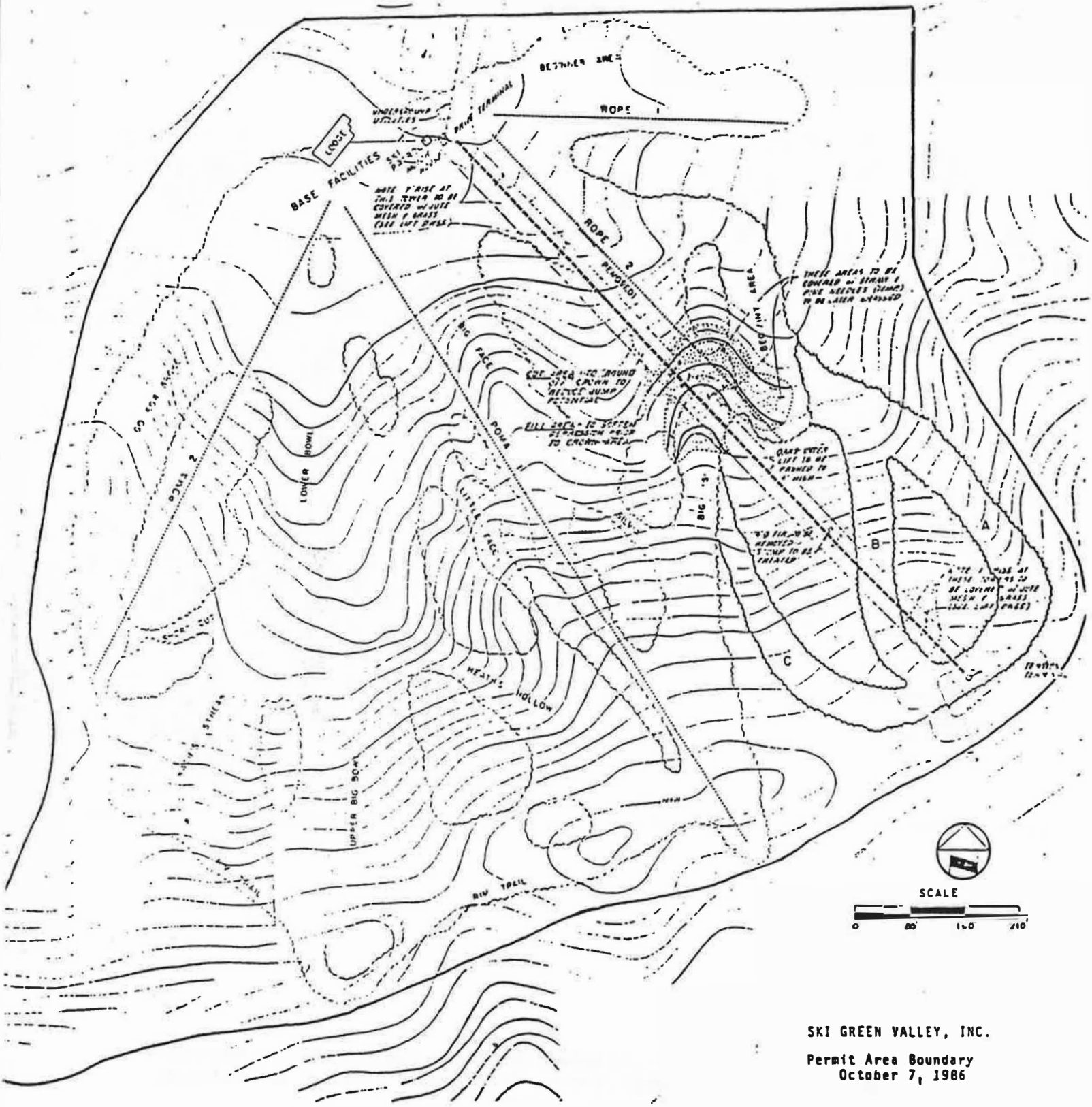

Fig. 2. Green Valley Ski Area, Arrowhead Ranger District, San Bernardino National Forest.

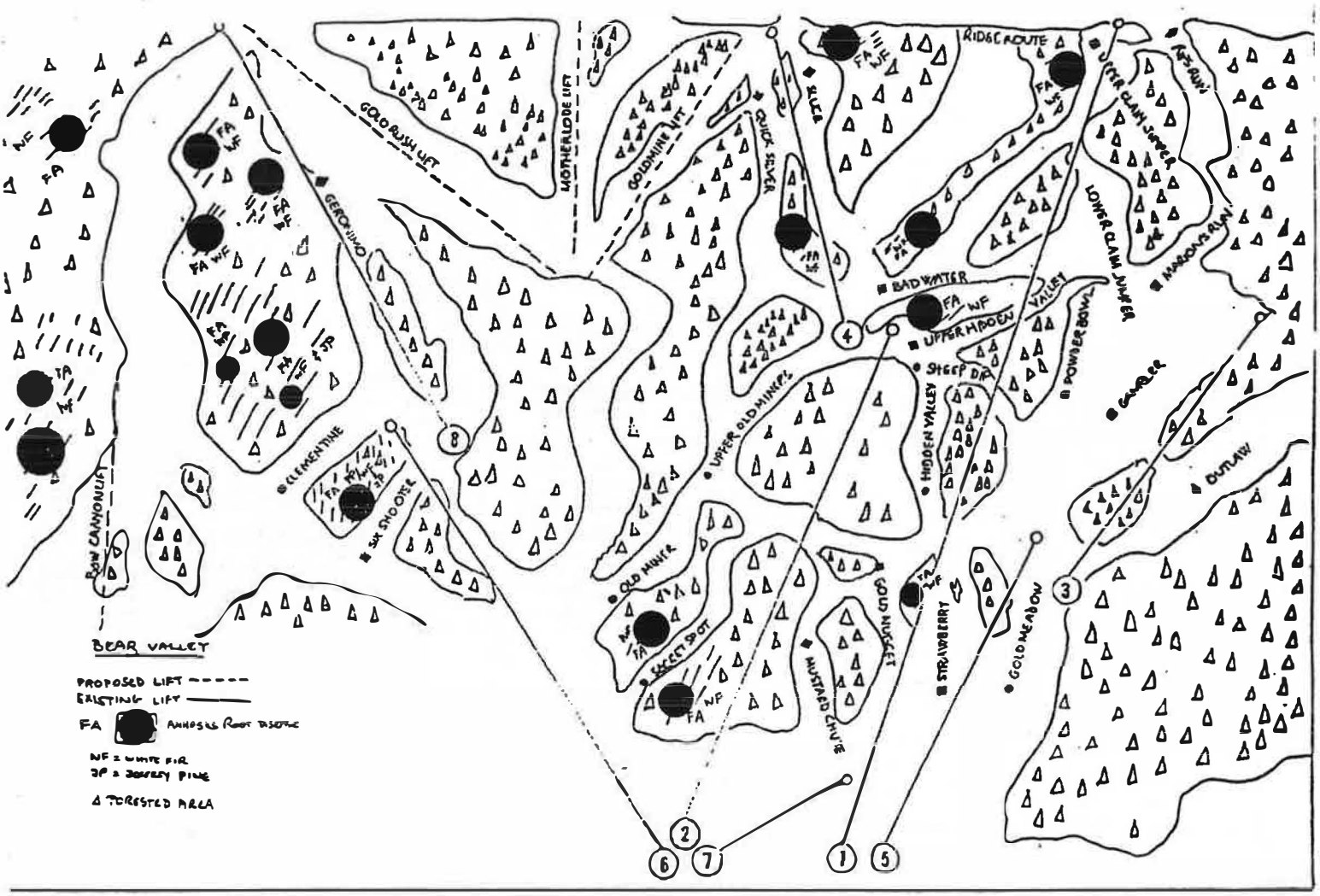

Fig. 3. Bear Valley (Goldmine) Ski Area, Big Bear Ranger District, San Bernardino National Forest. Dots denote location and relative size of annosus root disease centers.

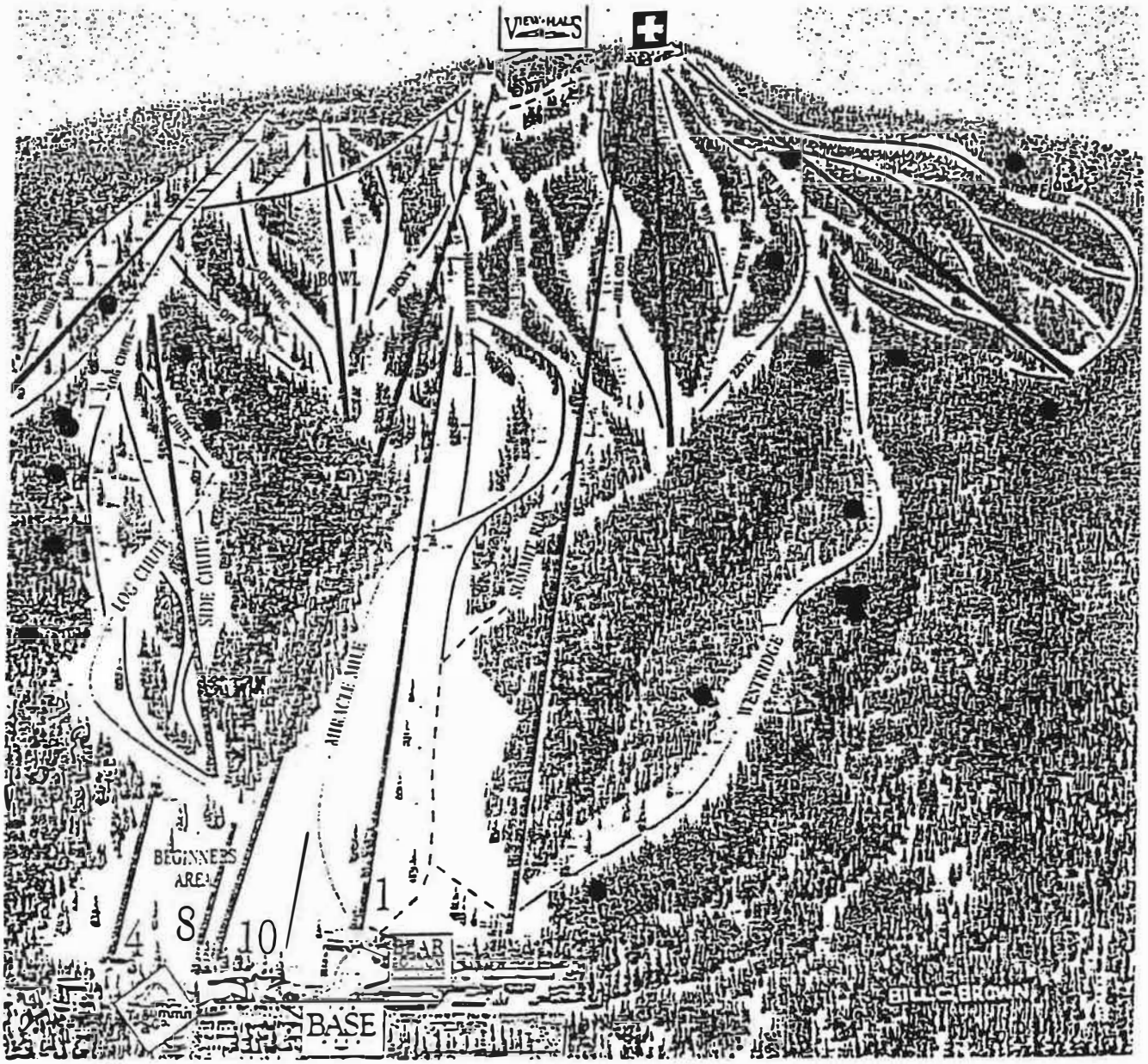

Fig. 4. Snow Summit Ski Area, Big Bear Ranger District, San Bernardino National Forest. Dots denote location of annosus root disease.

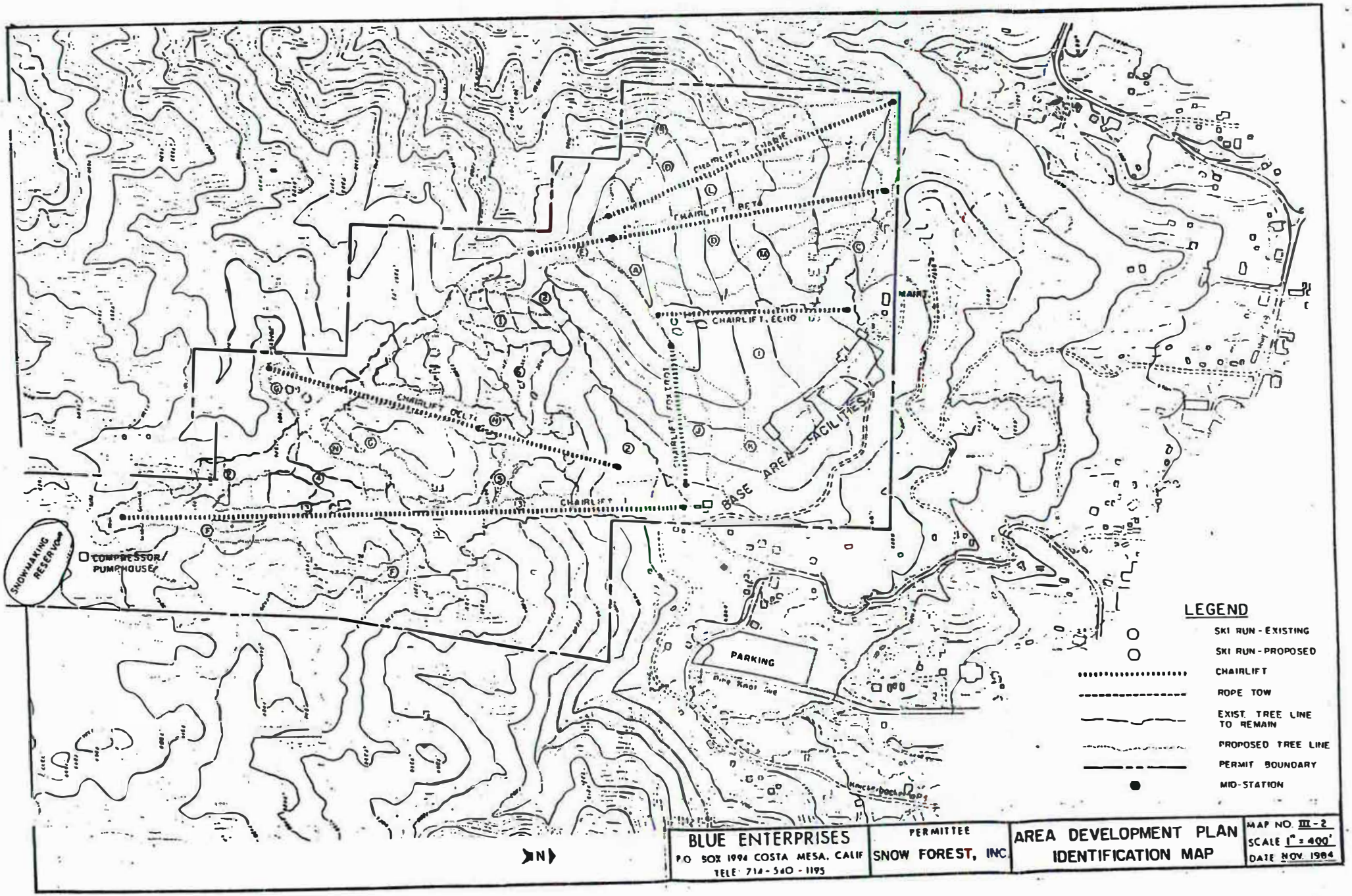

Fig. 5. Snow Forest Ski Area, Big Bear Ranger District, San Bernardino National Forest.